6. Cost Estimates and Analysis

Photo Source: Charlotte / Unsplash

6. Cost Estimates and Analysis

6.1 Cost Estimating Methodology

Estimates for the NSRL project follow industry best practices for large public transportation programs. The estimates are classified in accordance with the Association for the Advancement of Cost Engineering International (AACEi) Estimate Classification System. The System characterizes the level of design and of construction detail and establishes the appropriate ranges of contingency corresponding to these levels of detail.

The cost estimates within this report are not intended to set the final budget for the proposed project, but to allow for comparison of the alignments. The following parameters and guidance form the basis for the cost estimate:

- All costs are reported in 2018 US dollars and escalated to Quarter 1, 2028, the year that has been estimated as the midpoint of project construction. See Appendix E for more details.
- The cost analyses were performed in conjunction with the engineering and design process, and are based on the information available for each alignment, as well as key constructability issues identified by the project team.
- Research was conducted to determine comparable projects to NSRL. Individual benchmarking exercises were developed for key engineering and construction components (e.g., tunnel and station excavations). Refer to Appendix E for further details on the estimating methodology.

Definitions of the terms used in this chapter, such as indirect costs, additional costs, and soft costs, can be found in Appendix E under the Cost Methodology section.

6.2 Organization of the Cost Estimate

The costs are reported under general headings – stations, tunnels, etc. – for each of the following alternatives:

- The South Station Expansion (No NSRL) alternative
- The two-track tunnel alternatives (Central Artery Two-Track, South/Congress, and Pearl/Congress alignments)
- The four-track tunnel alternative (Central Artery Four-Track alignment)

There are two distinct components to the costs for each alignment – Tier 1 and Tier 2 costs.

Tier 1 costs capture the infrastructure costs needed to create the physical north-south rail connection within each alternative. Tier 1 costs do not include additional infrastructure in investments and rolling stock to achieve greater capacity increases beyond those achieved by the basic connection of the northern and southern rail systems.

Tier 2 costs capture the additional investments necessary to increase rail service to the levels defined in Section 4.3. Tier 2 items include upstream/downstream system improvements and additional trackwork, vehicles, and layover facilities.

There is a third category, Tier 3 costs, that is not included in the NSRL costs. This category encompasses potential project elements that were identified and costed out but not selected for inclusion in this Feasibility Reassessment (either because they were unnecessary for MBTA and would primarily benefit Amtrak, or because their costs were judged to be too high for the limited benefit they would provide). These project elements include electrification of the Lowell and Fairmount Lines, and works to widen Salem Tunnel. Details of these project elements and their costs can be found in Appendix E.

South Station Expansion (No NSRL) Alternative Costs

The total probable project costs for the South Station Expansion (No NSRL) alternative is approximately $1.7bn ($2.5bn in 2028) and include the following works, consistent with the South Station Expansion project scope* and allowing for service increases to North Station:

- Dorchester Avenue improvements: a half-mile of roadway improvements, including a new cycle track, a harborwalk for pedestrians, landscaping enhancement, realignment and reconstruction of the roadway (also includes reconstruction of a portion of the adjacent seawall), and improved stormwater management
- South Station headhouse: includes new amenities and better circulation for an improved passenger experience and improved multimodal connections
- South Station Expansion trackwork: additional platform capacity, extensions and modifications to the existing platforms, new elevated pedestrian concourse, all associated trackwork, and an overhead catenary system for the new platform tracks.

- Layover facilities – Widett Circle: includes a new transportation building; facility expansion to accommodate up to 26 additional trains, improvements to existing parking lot; drainage improvements, and all associated trackwork
- Layover facilities – Readville: includes a new transportation building, facility expansion to accommodate five to seven additional trains, improvements to the existing parking lot, drainage improvements, and all associated trackwork
- An allowance of $400m ($565m in 2028) has been made to account for all real estate acquisition costs and required relocation expenses related to right-of-way purchases

Total project costs are available in Table 18. Refer to Appendix E for the detailed estimate.

**While the separate South Station Expansion project itself generated cost estimates, independent estimates for its project components were developed as part of this NSRL Feasibility Reassessment.*

Tunnel Alignments

The total probable project costs for the three two-track tunnel alignments range from $6.1bn to $7.6bn ($8.6bn to $10.7bn in 2028). The probable costs for the four-track tunnel alignment are $12.6bn ($17.7bn in 2028). All tunnel alignments include the following works:

- Tunneling works segregated by construction methodology, based on alignment constraints and conceptual tunnel design (using TBMs or mined); including tunnel interior fit-out (assumed to be concrete) and allowances for tunnel systems (drainage, ventilation, fire protection, systems, power, and lighting)
- Station works segregated by construction methodology (within the TBM bore, cut-and-cover, or mined), including station fit-out and finishes for concourses, platforms, connecting tunnels, access shafts, elevators/escalators, and station systems
- Trackwork, including all civil works required for at-grade track; direct fixation track for the below-grade portion of the alignment, including rail, ties, clips, and pavement structure; allowance for special trackwork; and electrification to feed the traction power and signaling systems
- Portal works segregated by geographical location (North portals and Back Bay portal), including all civil works associated with the grade separations (retaining walls, excavations), track reconstructions, elevated structures for the North portals, electrification of the NSRL tunnel, and extension into the existing lines, as follows (and illustrated in Figure 48):
    - Fitchburg Line: electrification from NSRL tunnel to Porter Square Station
    - Lowell Line: electrification from NSRL tunnel to West Medford Station
    - Haverhill Line: electrification from NSRL tunnel to Malden Center
    - Rockport Line: electrification from NSRL tunnel to Chelsea Station
- Allowances as follows:
    - Underpinning works: based on 3-D models that identified areas of conflict with existing structures and buildings, segregated by geographical area
    - Allowances for roadway reconstructions throughout the project
    - Allowances for utility relocations
- Layover facility (no specific location identified) based on the Readville layover facility's total cost

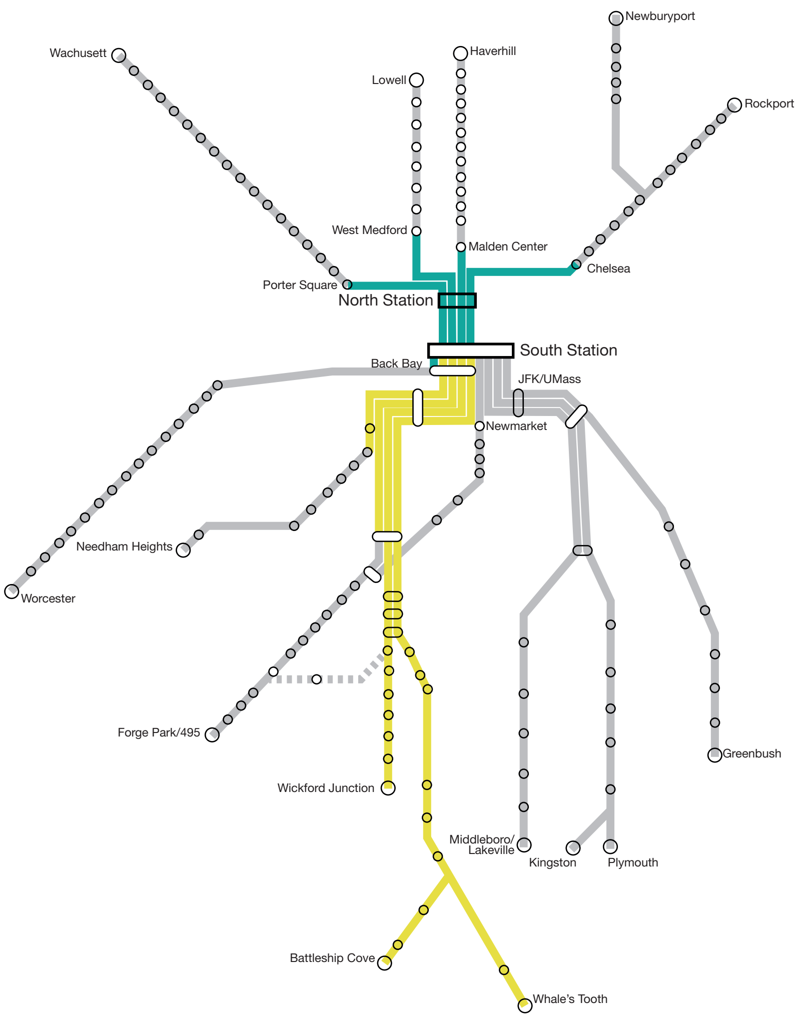

Figure 48: Proposed Electrification of the MBTA Commuter Rail system

Table 18 summarizes the total project costs for all alternatives. Refer to Appendix E for the detailed breakdown of the estimate.

Description	No NSRL	Two-Track			Four-Track
	South Station Expansion Costs ($)	Central Artery Costs ($)	Pearl/Congress Costs ($)	South/Congress Costs ($)	Central Artery Costs ($)
Dorchester Avenue Improvements	28,008,200	-	-	-	-
South Station Headhouse	234,712,500	-	-	-	-
Tunneling Works	-	1,002,782,600	1,181,777,700	1,344,447,400	2,384,042,400
Station Work	-	445,754,000	844,092,800	264,225,400	1,345,794,100
Trackwork	181,226,500	104,162,200	100,345,800	92,519,200	207,116,800
Portal Works	-	672,737,700	672,737,700	672,737,700	687,697,700
Allowances	-	145,491,000	168,538,000	162,367,500	150,684,200
Layover Facilities	163,288,800	33,973,400	33,973,400	33,973,400	33,973,400
Total Direct Cost	**607,236,300**	**2,404,900,900**	**3,001,465,400**	**2,560,270,600**	**4,809,308,600**
Indirect Costs	151,809,000	751,642,700	927,633,100	840,234,800	1,559,933,600
Subtotal D + I	**759,045,000**	**3,156,543,600**	**3,929,098,500**	**3,400,505,400**	**6,369,242,200**
Contractor's Contingency (10%)	75,904,500	315,654,400	392,909,900	340,050,600	636,924,300
Subtotal	**834,949,500**	**3,472,198,000**	**4,322,008,400**	**3,740,556,000**	**7,006,166,500**
OH & P (12%)	100,194,000	416,663,800	517,641,100	448,866,800	840,740,000
Total Construction Costs	**935,143,500**	**3,888,861,800**	**4,840,649,500**	**4,189,422,800**	**7,846,906,500**
Design / Engineering (9%)	84,163,000	349,997,600	435,658,500	377,048,100	706,221,600
Total DB Price	**1,019,306,500**	**4,238,859,400**	**5,276,308,000**	**4,566,470,900**	**8,553,128,100**
Soft Costs (15%)	152,896,000	635,829,000	791,446,200	684,970,700	1,282,969,300
Subtotal incl. Soft Costs	**1,172,202,500**	**4,874,688,400**	**6,067,754,200**	**5,251,441,600**	**9,836,097,400**
Tunneling Risk (40%)	N / A	867,221,200	1,022,018,900	1,154,049,800	2,061,755,000
Civil Works Risk (25%)	175,830,400	405,995,300	526,906,100	354,947,600	702,256,500
Subtotal Risk Costs	175,830,400	1,273,216,500	1,548,924,900	1,508,997,400	2,764,011,500
Subtotal Project Costs	**1,348,032,900**	**6,147,904,900**	**7,616,679,100**	**6,760,439,000**	**12,600,108,900**
ROW	400,000,000	N / A	N / A	N / A	N / A
Total Project Costs Qtr. 1 2018 USD	**1,748,032,900**	**6,147,904,900**	**7,616,679,100**	**6,760,439,000**	**12,600,108,900**
Escalation to 2028 (41%)	717,740,200	2,524,322,200	3,127,399,000	2,775,827,900	5,173,589,100
Total Project Costs Qtr. 1 2028 USD	**2,465,773,100**	**8,672,227,100**	**10,744,078,100**	**9,536,266,900**	**17,773,698,000**

Table 18: Summary of Tier 1 Project Costs for All Alternatives

**The South Station Expansion (No NSRL) Alternative corresponds to a Level 3 of the AACEi accuracy matrix, and the tunnel alternatives correspond to Level 5 (see Section 6.3)*

Figures 49 and 50 summarize the total cost composition for the South Station Expansion (No NSRL) and tunnel alignments, excluding any upstream/downstream improvement costs.

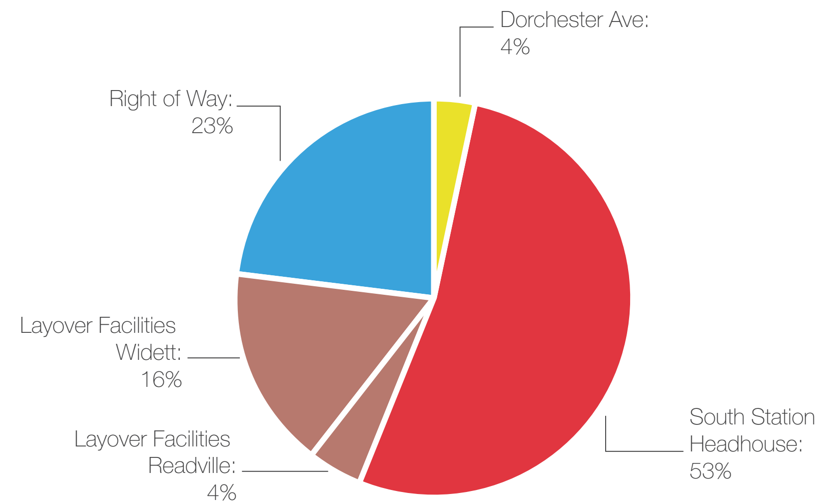

Figure 49: South Station Expansion (No NSRL) Alternative Cost Breakdown

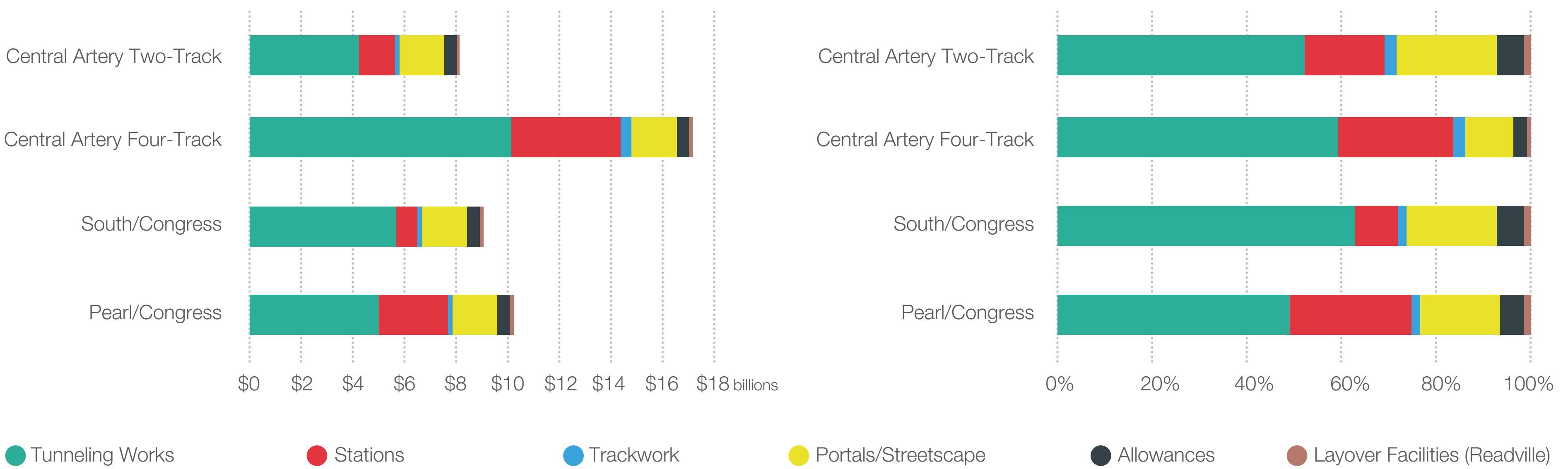

Figure 50: Tunnel Alignments Cost Breakdown (2028 USD)

Among the two-track alignments, the South/Congress alignment has higher tunneling costs than the other two alignments (Central Artery Two-Track and Pearl/Congress). This higher cost is because TBM tunneling costs are driven by the machine's external diameter — a 51-foot-diameter tunnel is exponentially more expensive than two tunnels 29-feet each in diameter or one single tunnel 41-feet in diameter. However, this increase in tunneling costs for the South/Congress alignment is offset by the savings in the mined excavation volumes for the stations, because the 51-foot-diameter TBM bore can accommodate the station platforms as well as the tracks.

The same analysis can be done between the Pearl/Congress and Central Artery Two-Track alignments, where the tunneling costs are similar, but the alignments differ greatly in their station costs. This is because, even though the construction methodology for South Station in the Central Artery Two- and Four-Track alignments requires a cofferdam, the cut-and-cover methodology for building stations remains considerably cheaper than the mined excavation methodology applied to both new underground stations in the Pearl/Congress alignment.

Vehicles – Baseline

The cost estimate for the vehicles includes the cost of the dual-mode locomotives. The South Station Expansion (No NSRL) alternative does not require the purchase of dual-mode locomotives; however, all tunnel alignment options have the same baseline vehicle purchase, as outlined in Table 19. The 'dual-mode swap' in the table refers to a possible credit for the sale of existing diesel locomotives that have not reached the end of their useful life.

Description	Total Costs ($)
Locomotive – Dual-Mode Swap	264,000,000
Total Rolling Stock Costs	264,000,000
Contingency (5%)	13,200,000
Total Rolling Stock Costs Qtr. 1 2018 USD	**277,200,000**
Escalation to 2028 MP Construction (41%)	113,818,000
Total Cost Qtr. 1 2028 USD	**391,018,000**

Table 19: Vehicles – Baseline for Tunnel Alignments

Tier 2 - Improvements

Additional Layover Facilities

The tunnel alignments include an additional layover facility (based on this Feasibility Reassessment's South Station Expansion Widett Circle costs) as part of Tier 2, to accommodate an increased fleet. Right-of-way purchased costs for layover facility are not included. Table 20 summarizes the capital costs of the facility.

Description	Total Costs ($)
Layover Facilities (Widett Circle)	129,315,400
Total Direct Costs	**129,315,400**
Indirect Costs (25%)	32,328,900
Subtotal D + I	**161,644,300**
Contractor's Contingency (10%)	16,164,500
Subtotal	**177,808,800**
Overhead & Profit (12%)	21,337,100
Total Construction Costs	**199,145,900**
Design / Engineering (9%)	17,923,200
Total Design Build Price	**217,069,100**
Soft Costs (15%)	32,560,400
Subtotal Incl. Soft Costs	**249,629,500**
Project Risk Contingency (15%)	37,444,500
Total Project Costs Qtr. 1 2018 USD	**287,074,000**
Escalation to 2028 MP Construction (41%)	117,872,300
Total Cost Qtr. 1 2028 USD	**404,946,300**

Table 20: Additional Layover Facility Costs

Upstream/Downstream Improvements

The upstream/downstream improvement works, ranging from $590m to $650m ($830m to $915m in 2028), are similar for all alternatives (including the South Station Expansion - No NSRL alternative) and include the following:

- Extra platform capacity (Fitchburg, Franklin, Lowell, Providence/Stoughton, and Worcester Lines)
- Double-tracking improvements (including signaling but excluding electrification for an overhead catenary system) along some or all of the Fitchburg, Needham, Old Colony, Haverhill, and Newburyport/Rockport Lines
- Resignaling of critical points on multiple lines (totaling 30 track miles)
- Turnback crossovers (Franklin and Fairmount Lines)

Table 21 summarizes the total project costs for the upstream/downstream improvements for the South Station Expansion (No NSRL) alternative and the two-track and four-track alignments. Refer to Table E-3 in Appendix E for the detailed estimate.

Description	South Station Expansion (No NSRL) Costs ($)	Two-Track Tunnel Costs ($)	Four-Track Tunnel Costs ($)
Additional platform capacity	17,000,000	12,750,000	17,000,000
Track doubling	95,251,200	120,213,600	120,213,600
Additional Crossovers	3,000,000	4,500,000	4,500,000
Resignaling	150,750,000	150,750,000	150,750,000
Total Direct Costs	**266,001,200**	**288,213,600**	**292,463,000**
Indirect Costs (25%)	66,500,300	72,053,400	73,115,900
Subtotal D + I	**332,501,500**	**360,267,000**	**365,579,500**
Contractor's Contingency (10%)	33,250,200	36,026,700	36,558,000
Subtotal	**365,751,700**	**396,293,700**	**402,137,500**
Overhead & Profit (12%)	43,890,300	47,555,300	48,256,500
Total Construction Costs	**409,642,000**	**443,849,000**	**450,394,000**
Design / Engineering (9%)	36,867,800	39,946,500	40,535,500
Total Design Build Price	**446,509,800**	**483,795,500**	**490,929,500**
Soft Costs (15%)	66,976,500	72,569,400	73,639,500
Subtotal Incl. Soft Costs	**513,486,300**	**556,364,900**	**564,569,000**
Project Risk Contingency (15%)	77,023,000	83,454,800	84,685,400
Total Project Costs Qtr. 1 2018 USD	**590,508,300**	**639,819,700**	**649,254,400**
Escalation to 2028 MP Construction (41%)	242,462,400	262,709,200	266,583,100
Total Cost Qtr. 1 2028 USD	**832,971,700**	**902,528,900**	**915,837,500**

Table 21: Summary of Total Project Costs for Upstream/Downstream Improvements

Vehicles – Increase

The vehicle increase scenario is summarized in Table 22 for the South Station Expansion (No NSRL) alternative, the two-track tunnel (same for all alignments), and the four-track tunnel alignments. In this table, dual-mode locomotive swap shows a credit in order to supersede the monies allocated in Tier 1 for this same item.

Description	South Station Expansion (No NSRL) Costs ($)	Two-Track Tunnel Costs ($)	Four-Track Tunnel Costs ($)
Locomotive – Dual-Mode Swap (from baseline)	-	(72,000,000)	(32,000,000)
Locomotive – Dual-Mode Increment	-	792,000,000	792,000,000
Diesel Locomotive Increment	385,000,000	-	-
Coaches Increment	558,000,000	609,000,000	609,000,000
Battery-Electric Helper Locomotives	-	14,000,000	14,000,000
Subtotal Rolling Stock Costs	**943,000,000**	**1,343,000,000**	**1,383,000,000**
Contingency (5%)	47,150,000	67,150,000	69,150,000
Total Rolling Stock Costs Qtr. 1 2018 USD	**990,150,000**	**1,410,150,000**	**1,452,150,000**
Escalation to 2028 MP Construction (41%)	406,554,400	579,005,900	596,251,000
Total Cost Qtr. 1 2028 USD	**1,396,706,400**	**1,989,155,900**	**2,048,401,000**

Table 22: Vehicle Costs

Table 23 shows the total costs for each alternative, showing subtotals for each of the tiers, in 2028 US dollars.

	No NSRL	Two-Track			Four-Track
Description	South Station Expansion Costs ($)	Central Artery Costs ($)	Pearl/Congress Costs ($)	South/Congress Costs ($)	Central Artery Costs ($)
Total Alternative Project Cost	2,465,773,100	8,672,227,100	10,744,078,100	9,536,266,900	17,773,698,000
Vehicles - Baseline	-	391,018,000	391,018,000	391,018,000	391,018,000
Total Tier 1 Costs	**2,465,773,100**	**9,063,245,100**	**11,135,096,100**	**9,927,284,900**	**18,164,716,000**
Additional Layover Facilities	-	404,946,300	404,946,300	404,946,300	404,946,300
Total Upstream/ Downstream Improvement Costs	832,971,700	902,528,900	902,528,900	902,528,900	915,837,500
Vehicles – Increase	1,396,704,400	1,989,155,900	1,989,155,900	1,989,155,900	2,048,401,000
Subtotal Tier 2 Costs	**2,229,676,100**	**3,296,631,100**	**3,296,631,100**	**3,296,631,100**	**3,369,184,800**
Total Tier 1 + Tier 2 Costs	**4,695,449,200**	**12,359,876,200**	**14,431,727,200**	**13,223,916,000**	**21,533,900,800**

Table 23: Summary of Costs by Tier (2028 USD)

6.3 Basis of Estimate

Based on the level of design completed for this Feasibility Reassessment, this estimate is classified as a Level 3 Budget Authorization for the South Station Expansion (No NSRL) alternative and a Level 5 Rough Order of Magnitude estimate for the tunnel alignments. These classifications are per the classification matrix in Table 24, which has been developed in accordance with AACEi's best practices. The table is based on the AACEi Cost Estimate Classification Matrix, which indicates an industry best practice accuracy range and estimate methodology, in relation to the level of design completeness.

Estimate Level	Estimate Description	Design Phase	Level of Completion	Methodology	Accuracy Range
5	Rough Order of Magnitude	Planning Schematic Design	0% to 5%	Parametric Models Capacity Factored Historical Costs	L: -20% to - 50% H: +30% to +100%
4	Concept Feasibility	Planning Schematic Design	1% to 15%	Equipment Factored Parametric Models	L: -15% to - 30% H: +20% to +50%
3	Budget Authorization	Planning Schematic Design Design Documents	10% to 40%	Unit Costs Assembles	L: -10% to - 20% H: +10% to +40%
2	Budget Control Estimate	Preliminary Design Engineering Design Documents Construction Documents	30% to 70%	Detailed Unit Cost Detailed Take-Off	L: -5% to - 15% H: +5% to +30%
1	Bid	Detailed Design Engineering Construction Documents	50% to 100%	Detailed Unit Cost Detailed Take-Off Productivities Subcontractor Quotes	L: -2% to - 5% H: +3% to + 15%

Table 24: AACEi Estimate Classification Matrix

The accuracy ranges with respect to the AACEi Estimate Classification Matrix account for potential fluctuation in the market above standard yearly escalation and changes in the project cost with respect to design development and refinement. Table 25 summarizes the accuracy ranges for the developed estimates.

	Accuracy Range (Low)	Accuracy Range (High)
South Station Expansion - No NSRL (Level 3 Estimate)	-20%	+40%
Tunnel Alignments (Level 5 Estimate)	-30%	+50%
Upstream/Downstream Improvements (Level 5 Estimate)	-50%	+100%

Table 25: Estimate Accuracy Ranges

6.4 Assumptions and Exclusions

The project cost estimate was performed with the following assumptions:

1. For the South Station Expansion (No NSRL) alternative, an allowance of $400m ($565 in 2028) has been made to account for all real estate acquisition costs and required relocation expenses related to right-of-way purchases.
2. For the tunnel alignments, it has been assumed that the real estate acquisitions for all tunneling, station, and portal works will be covered by the net sales of proceeds, and therefore no incremental cost has been assumed in the estimate.
3. For the tunnel alignments, it has been assumed that no service interruption or constrained work hours will affect the schedule of construction, and therefore no premium has been included to account for this.
4. It has been assumed that there are no right-of-way constraints for layover yards and staging areas within the vicinity of the project, and therefore no additional costs have been included to account for this.
5. No allowances have been made in the direct costs for hazardous material removal and disposal.
6. It has been assumed that there will be no constraints in disposal sites to allow for the disposal of the large quantity of excavated material (>2 million cubic yards).

l = 20 x tunnel diameter

w = 2 x diameter x # of tunnels x 1.25

d (1) = 2.5 x diameter if diameter = 29ft

d (2) = 2 x diameter if diameter = 41.5ft

d (3) = 1.6 x diameter if diameter = 51.2ft

Figure 51: TBM Launch Pit Schematic

7. TBM launch pit quantities have been calculated based on the schematic in Figure 51.
8. Utility relocation allowances have been made based on benchmarks from other projects and broken down by utility relocations at stations and utility relocations for tunnel works.
9. It has been assumed that the trackwork inside the tunnels will be direct fixation, i.e., concrete embedded.
10. A 25% productivity reduction factor has been included in the Back-Bay portal civil works.

6.5 Schedule

Overview of Schedule

A high-level procurement and construction schedule was developed for the South Station Expansion (No NSRL) and tunnel alignments, based on production rate benchmarks for similar projects. Different schedules have been produced for each alternative.

Figures 52 and 53 show the high-level schedule for each alternative.

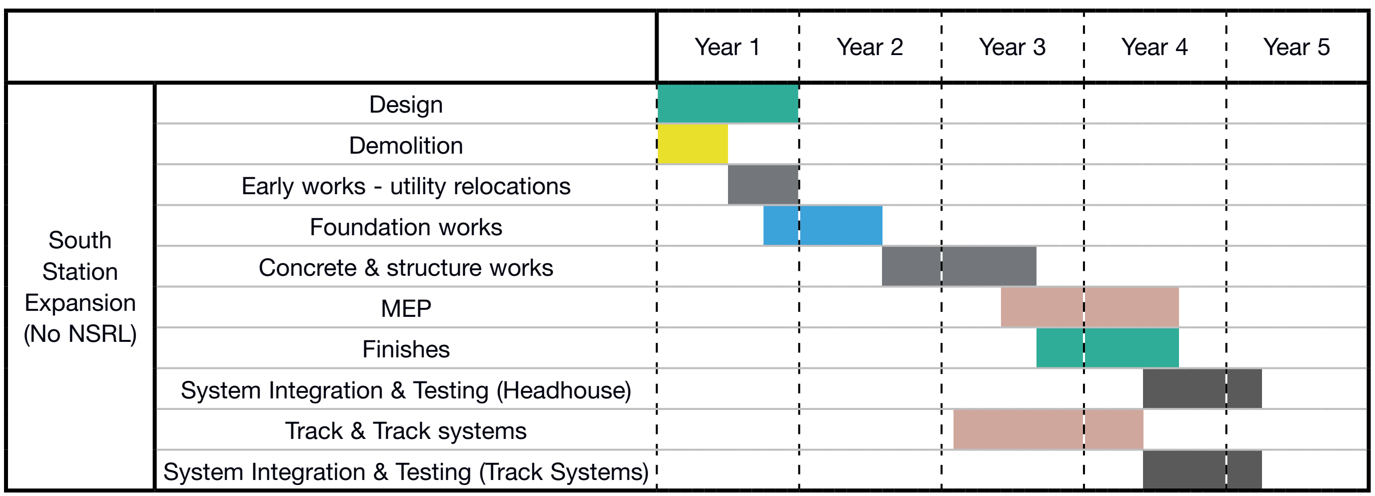

Figure 52: Schedule Summary for the South Station Expansion (No NSRL) Alternative

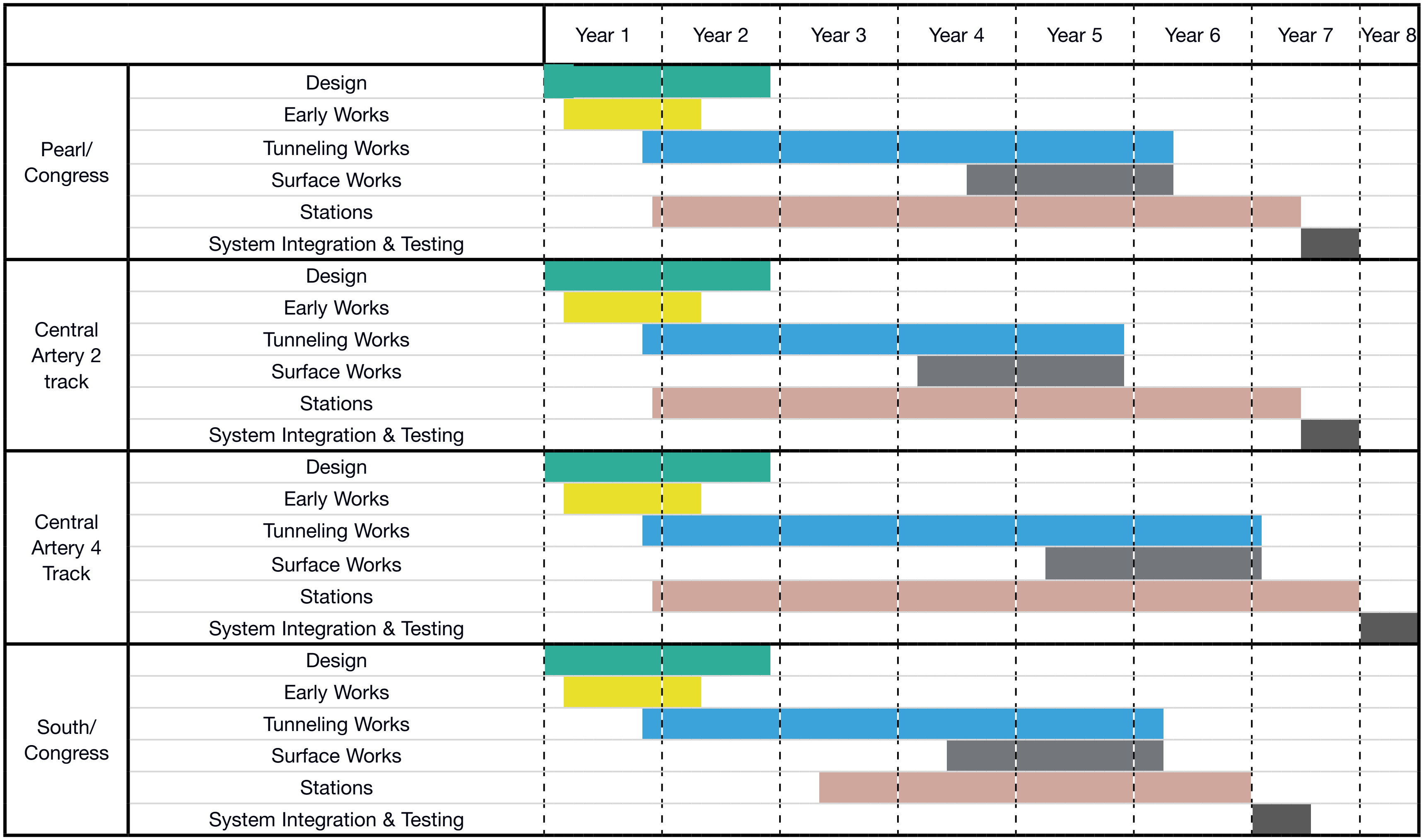

Figure 53: Schedule Summary for All NSRL Tunnel Alignments

Basis of Schedule

The schedule is a Class 5 schedule per AACEi Recommended Practice document 27R-03 (see Table 26). Schedule accuracy is dependent on the work sequencing and chosen construction means and methods. The schedule presented represents a single alternative for sequencing. Alternative sequencing options may produce a more optimized schedule.

Schedule Class	Primary Characteristic	Secondary Characteristic	
	Degree of Project Definition (Expressed as percent of complete definition)*	End Usage	Scheduling Methods Used
Class 5	0% to 2%	Concept screening	Top-down planning using high-level milestones and key project events.
Class 4	1% to 15%	Feasibility study	Top-down planning using high-level milestones and key project events. Semi-detailed.
Class 3	10% to 40%	Budget, authorization, or control	"Package" top-down planning using key events. Semi-detailed.
Class 2	30% to 70%	Control or bid/tender	Bottom-up planning. Detailed.
Class 1	70% to 100%	Bid/tender	Bottom-up planning. Detailed.

Table 26: AACEi Schedule Classification Matrix

**RP 18R-97 provides the range in percentages for each class.*

7. Benefits Analysis

Photo Source: Wikimedia Commons, User Pi.1415926535

7. Benefits Analysis

The NSRL project has been expected to generate benefits to rail passengers, transportation system users and the broader public. The Problem Statement in Chapter 2 outlined the current system deficiencies, which the project seeks to resolve. This chapter identifies the anticipated performance of the project, including its social and economic impacts. These benefits range across six categories:

- Mobility Impacts – Includes increased ridership, travel time savings, and mode shift from automobile to transit
- Employment Access – How the NSRL project affects access to employment compared to the No Build scenario.
- Operational Efficiencies – The impact of rail unification on the overall state of good repair of the rail system, including operational efficiencies
- Economic Impacts – Potential development opportunities directly attributable to the project and effects from construction and operation expenditures
- Environmental Justice Impacts – How the NSRL project affects fair access to housing and economic opportunities, particularly for environmental justice (EJ) communities
- Air Quality Impacts – Determine environmental and public health impacts to the extent possible

While there may be other benefits that accrue from an investment like the NSRL (such as increased development or tourism potential across the MBTA Commuter Rail system), MassDOT's analysis focused on the listed benefits as they can be significant and can be measured with available data. Benefits that rely on changes to local land use controls, over which MassDOT has no jurisdiction, were deemed to be speculative and not necessary for an assessment of the project's overall benefit.

A standardized methodological framework was used to assess quantifiable benefits: the No Build and the build alternatives are compared to measure the incremental value that the NSRL project creates in the region. All dollar amounts are in 2018 USD.

Most of the project's benefits derive from its effect on the total transportation system, which in turn impacts the activities of area residents. The CTPS ridership forecasts are the basis for the benefits analysis, as changes in MBTA Commuter Rail ridership impact other parts of the transit system as well as the highway system. These impacts can then affect emissions and equity. Other project benefits are closely related to the expenditure of resources necessary to deliver the project and operate the system, and those expenditures ripple through the regional economy.

7.1 Methodology for Quantifiable Benefits

Quantifiable benefits were measured by comparing the No Build against the build alternatives.

Definition of the No Build and Build Alternatives

No Build

The No Build alternative corresponds to the physical and economic environment absent the NSRL facility and its proposed operations, and assesses the consequences of the project not taking place. This alternative represents the reference point against which the incremental benefits and costs of the NSRL build alternatives will be measured.

The No Build alternative does not assume the status quo or today's conditions – it includes all the projects and programs identified in the fiscally constrained Regional Transportation Plan (RTP) adopted by the Boston Region MPO, including various MBTA Commuter Rail improvements as well as rapid transit, bus and highway projects. The South Coast Rail alignment via Middleborough is also included, but the South Station Expansion project is not included in the RTP and hence is not included in the No Build alternative. The No Build alternative (as well as all of the build alternatives) assumes the region's forecast employment and population growth as developed by MAPC (the Boston region's planning agency) per the currently endorsed MetroFutures regional land use plan.

The Build Alternatives

The benefits analysis considers three build alternatives. Chapter 4 defines the service characteristics of the alternatives, and their physical characteristics are detailed in Chapter 5 and costed in Chapter 6. These three alternatives and their associated service assumptions are as follows:

- Surface, or South Station Expansion & All-Day Peak Service (No NSRL) – This alternative assumes that South Station is expanded to 20 tracks (a 50% increase in capacity) as per the proposals of the South Station Expansion project, three to four additional trains operate in the peak hour, and peak-period service levels continue throughout the day. At North Station, an additional two trains are added in the peak hour (accommodated by the North Station Bridge rebuild project) and the peak-period service levels operate throughout the day.
- Two-Track, or NSRL All-Day Peak Service (Two-Track). Physical alignments are Central Artery, South/Congress or Pearl/Congress) – In this alternative, a two-track tunnel is assumed and peak period service operates throughout the day (essentially at the same service frequencies as the South Station Expansion alternative, with slightly more service to the north side suburbs). In Chapter 4, a service variation for the Two-Track tunnel reduced service midday. That variation is not considered in the benefits analysis to allow consistency among all the build alternatives. For the purposes of the benefits analysis, the three Two-Track alignments are considered as having equal ridership and economic benefits; however, a separate analysis of changes in each alignment's Downtown catchment area is provided.
- Four-Track, or NSRL All-Day Peak Service (Four-Track) – In this alternative, in addition to the service operated by the NSRL All-Day Peak Service (Two-Track) alternative, the Fairmount Line is routed through a separate two-track tunnel, creating a four-track system.

7.2 Mobility Impacts

Transit improvements can generate mobility benefits to both users and non-users of the transit network. Some of these benefits were quantified through CTPS' travel demand model, based on 2040 population and employment forecasts (model assumptions, framework, and outputs are described in detail in Appendix C). This model aims to predict traveler behavior using different transportation infrastructure networks and pricing structures. Other changes to traveler behavior, such as comfort, legibility and reliability, are subtler and more difficult to quantify.

An important consideration in the benefits discussion concerns the travel model's reliance on existing behavior. This behavior is based, in turn, on existing infrastructure. As a result, the model cannot anticipate regional travel shifts (for example, more people moving to the municipalities on the north side of the MBTA Commuter Rail system while keeping jobs in Back Bay and the Boston Financial District) or even the willingness of companies to locate along north side commuter rail lines as a result of the improved access into Downtown Boston and the municipalities on the south side of the rail network.

Figure 54 illustrates the quantifiable benefits considered in this analysis and their CTPS source data. All build alternatives are expected to generate similar benefits, but the magnitude of the benefits vary with each alternative.

Improvements in service frequency (assumed in all build alternatives) and in connectivity through the construction of the NSRL tunnel (both the Two-Track and Four-Track build alternatives) will result in:

- **Travel time savings for MBTA Commuter Rail users** as wait times would be reduced due to more frequent service.
- **Reduced crowding on parallel MBTA rapid transit lines** as commuter rail improvements serve to relieve crowding on parallel or connecting rapid transit lines.
- **Travel time savings for travellers who shifted from automobile to MBTA Commuter Rail** as improvements in commuter rail service are expected to make this mode choice more attractive and induce automobile drivers to shift modes.
- **Mode shift from automobile to MBTA Commuter Rail** which in turn will generate benefits to roadway users and the broader public:
  - **Reduction in vehicle miles traveled** (VMT) as there are fewer vehicles on the road
  - **Reduction in vehicle emissions** as there will be fewer vehicle miles travelled
  - **Potential savings in travel time from auto drivers** as there is a reduction in the number of vehicles on the roadway system (opening up more capacity)

Safety benefits from accident reduction were not considered because there is no consistent paradigm to measure the consequences of having fewer vehicles on the roadway system. As an example, fewer vehicles on the roadway can lead drivers to drive faster and result in higher-severity accidents.

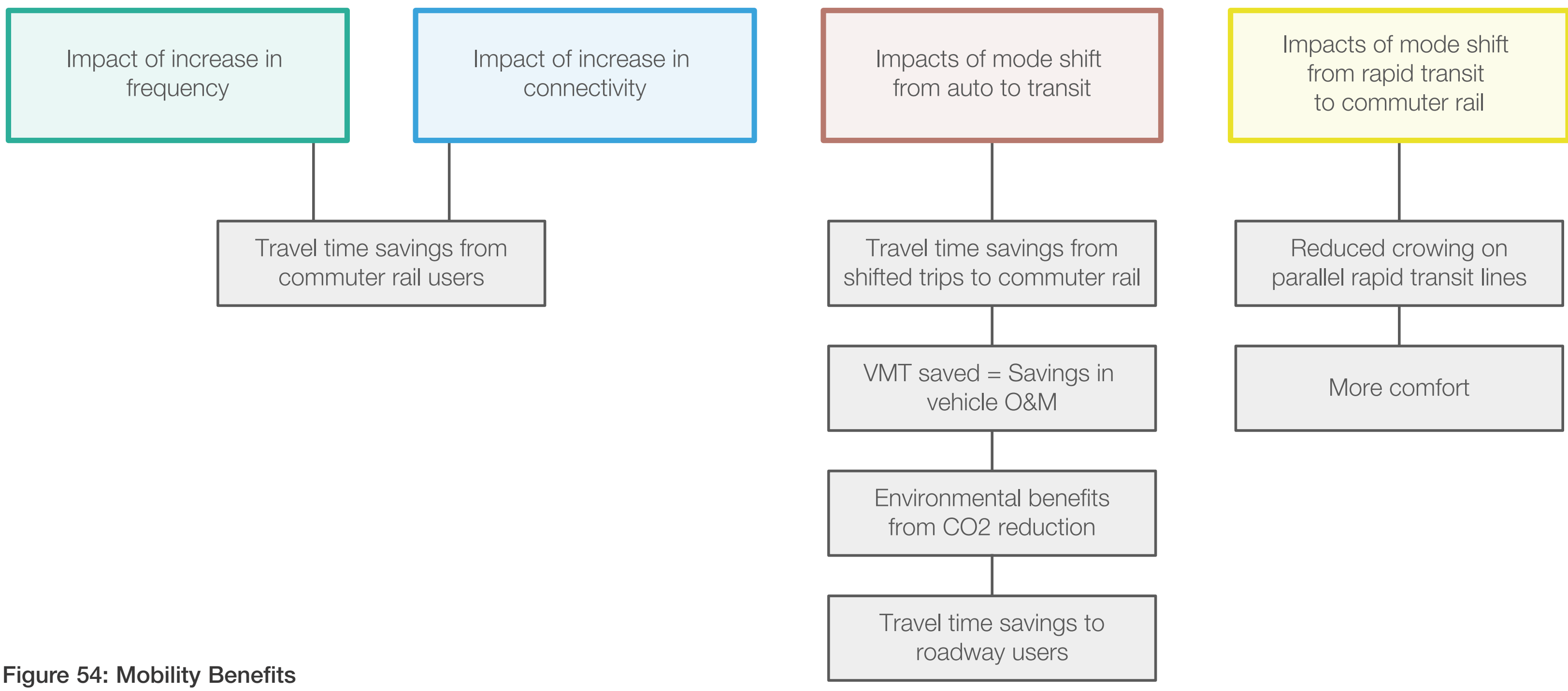

Figure 54: Mobility Benefits

Ridership and Mode Shift

The NSRL project, as noted in Chapter 4, creates more transportation capacity into Downtown Boston – anywhere from about 44,000 No Build peak-hour seats to almost 60,000 peak-hour seats with the NSRL All-Day Peak Service (Two-Track) alternative.

The results from the CTPS model forecast daily 2040 No Build commuter rail ridership of about 150,000 trips. More than 60% of passengers begin their trips on routes currently serving South Station, with the balance – less than 40% – using trains destined for North Station. This is consistent with existing travel patterns. As service is improved and the connectivity between North and South Stations via the NSRL tunnel is made viable through the Two-Track and Four-Track build alternatives, ridership from the north side of the rail system increases more than from the south side, in relative terms.

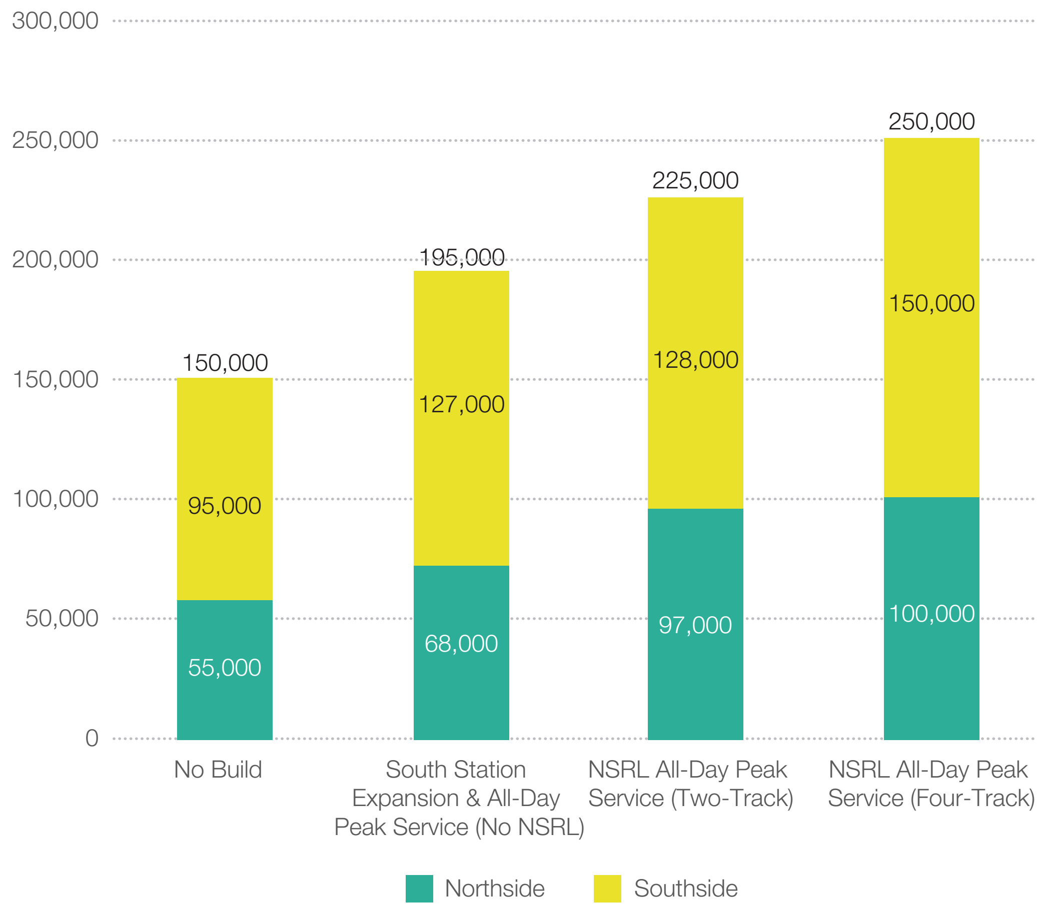

Figure 55. 2040 Commuter Rail Ridership by Alternative (Daily one-way trips)

Source: Ridership data from CTPS model. Note: Totals rounded.

As summarized in Chapter 4, ridership increases in each of the build alternatives. However, the benefits of these increases are different depending on its specific alignment.

In the **South Station Expansion & All-Day Peak Service (No NSRL)** alternative (the build alternative lacking the NSRL Tunnel), the frequency and service increases (enabled by the higher capacity at South Station) and the increase in service to North Station increase ridership as illustrated in Table 27.

For the south side of the commuter rail network, trips outside Route 128 dominate the travel market, reflecting the large rider base on the Providence and Franklin Lines. As service levels increase, however, off-peak trips are equally split between those from within and outside Route 128. The north side of the network generates more trips from within Route 128 than from outside.

In the **NSRL All-Day Peak Service (Two-Track)** alternative, ridership from the south side does not increase beyond that forecast in the South Station Expansion & All-Day Peak Service (No NSRL); however, ridership from the north side increases.

Compared to the No Build scenario, the north side of the commuter rail system experiences a large ridership increase – more than 75%. At least two-thirds of this increase is solely related to the improved tunnel connection into Downtown Boston (a total of almost 30,000 trips). On the north side of the rail system, the split between origins within

Origin Area	Daily Ridership Increase	Percentage Increase	All Trips from Inside Route 128	All Trips from Outside Route 128
South Side	32,000	34%	25%	75%
North Side	13,000	24%	55%	45%

Table 27: South Station Expansion & All-Day Peak Service (No NSRL) Ridership Origins

Source: Estimates based on CTPS travel demand model

Origin Area	Daily Ridership Increase	Percentage Increase	All Trips from Inside Route 128	All Trips from Outside Route 128
South Side	33,000	34%	40%	60%
North Side	42,000	75%	55%	45%

Table 28: NSRL All-Day Peak Service (Two-Track) Ridership Origins

Source: Estimates based on CTPS travel demand model and outside Route 128 remains consistent with the South Station Expansion & All-Day Peak Service (No NSRL) alternative. From the south side, the provision of the tunnel increases ridership within Route 128 in the off-peak to about 60%, which in turn reduces the daily split to 60%/40%, favoring trips beyond Route 128.

In the **NSRL All-Day Peak Service (Four-Track)** alternative, ridership trends mimic the NSRL All-Day Peak Service (Two-Track) alternative.

A comparison of the South Station Expansion & All-Day Peak Service (No NSRL) alternative and the Two-Track and Four-Track build alternatives shows an increase in ridership from the north side. In the tunnel build alternatives, 40-45% of passengers are originating from the north side, even though ridership on the south side lines increases. This roughly 5% shift towards north side originating traffic compares to the existing system ridership split of about 60-65% from the south and about 35-40% from the north.

Gateway Cities

The Commonwealth of Massachusetts identifies Gateway Cities as midsize urban centers anchoring regional economies. During their industrial heyday, these economic and industrial hubs offered residents good jobs and a "gateway" to the American Dream. However, during the last several decades, manufacturing jobs slowly disappeared. While Greater Boston benefited from "new economy" jobs, Gateway Cities have been slow to draw similar interest or investment. As part of a renewed focus on these areas, studies and proposals suggest that land use and infrastructure changes (such as the NSRL) may enable Gateway Cities to again serve as economic catalysts. Small entrepreneurial businesses that fuel job creation in today's economy may be attracted to walkable and innovative urban environments, like the ex-industrial, relatively dense Gateway Cities. MassINC, a regional think tank, reports that "Gateway City TOD will produce a heavy stream of new riders; the commuter rail system has capacity to carry these additional passengers with limited marginal cost". The MassINC report also notes that improved transportation is a key part of its strategic vision for a "Transformational Gateway City TOD".[22]

Within the MBTA Commuter Rail service area are 25 Gateway Cities, and there are commuter rail stations in 16 of these cities. In the build alternatives, service is substantially increased to 11 of these cities (Gateway Cities on the Old Colony Lines and the South Coast Rail extension have limited service increases due to upstream capacity constraints).

The average ridership increase related to the Two-Track and Four-Track build alternatives is about 35% on the south side of the rail system and about 75% on the north side of the rail system; however, Gateway Cities' ridership changes are more pronounced.

Table 30 identifies the ridership increase in north side and south side Gateway Cities directly served by the MBTA Commuter Rail.

Origin Area	Daily Ridership Increase	Percentage Increase	All Trips from Inside Route 128	All Trips from Outside Route 128
South Side	55,000	58%	45%	55%
North Side	45,000	82%	55%	45%

Table 29: NSRL All-Day Peak Service (Four-Track) Ridership Origins

Source: Estimates based on CTPS travel demand model

The provision of additional service and the tunnel alternatives have marginal benefits for the southern Gateway Cities (Worcester and Attleboro); however, Gateway Cities north of Boston experience significant ridership gains, from an increase in service frequency and substantially with the provision for direct service to Downtown Boston and Back Bay. The higher service frequencies almost double ridership from north side Gateway Cities, and direct service to Downtown Boston almost triples ridership, compared to the No Build alternative.

	No Build	South Station Expansion & All-Day Peak Service (No NSRL)	Change (%)	NSRL All-Day Peak Service (Two-Track)	Change %
North Side Gateway Cities	8,136	15,598	92%	23,493	189%
South Side Gateway Cities	4,459	5,115	15%	5,031	13%

Table 30: Gateway Cities Commuter Rail Ridership Increases, by Alternative

Source: Project Analysis of CTPS Data, both directions of travel.

Transit Access to Employment

As described in Section 5, each Two-Track alignment (Central Artery, South/Congress, and Pearl/Congress) has its own combination of two station locations (the Four-Track alignment – Central Artery - has three stations). These combinations provide access to slightly different areas of Downtown Boston, based on the locations of their indicative entrances and exits, or “headhouses”.

A number of analyses were conducted to determine the accessibility benefits of each alignment and focused on the accessibility changes related to the locations of the proposed stations relative to the existing South Station and North Station. A key accessibility benefit is the number of jobs accessible within a ten-minute walk from the center of each station location. Table 31 summarizes the job catchment for each alternative and its station combination using 2040 predictions for job growth from CTPS, to align with the build year for the NSRL project.

Several steps were completed to draw the boundaries circumscribing a ten-minute walk from the center of each station and to then calculate the number of 2040 jobs that fall within these boundaries, as follows:

- For underground stations only, it was first assumed that passengers have an in-station travel time of three minutes before exiting the station from one of the headhouses.
- It was then assumed that passengers walk at a speed of about three miles per hour (equivalent to about 4.5ft per second) for ten minutes (for the existing condition and No Build surface stations) and the remaining seven minutes (for underground stations).
- The above yields a walkshed of about 1,900ft (approximately 0.36 miles) per seven minutes.
- The number of jobs within each resultant walkshed were then calculated by identifying which standard census areas (traffic analysis zones, or TAZs) fell within those walksheds. The relevant CTPS 2040 jobs data were queried on an 'all-or-nothing' rule. If the center of the TAZ touches the headhouse's walkshed, it was counted. An additional 125ft in either direction was allowed for some edge cases, to determine whether a TAZ employment is considered.

Alignment Name	Stations	Total Employment (2040)
No Build	Existing North and South Station headhouses/exits	155,311
Surface (No NSRL)	Existing North and South Station headhouses/exits	155,311
Central Artery Two-Track	New South Station and North Station headhouses/exits	158,820
Central Artery Four-Track	New South Station, Central Station and North Station headhouses/exits	172,656
South/Congress	New South Station and North Station headhouses/exits	163,935
Pearl/Congress	New South Station and North Station headhouses/exits	158,826

Table 31: 2040 Employment Within 1,900ft (~7 Min Walk) from Station Headhouses (Existing and Proposed), by Alignment

- The walksheds for each station headhouse were merged and a total walkshed for each alignment was created. Total job counts for these walksheds were calculated, subtracting any within overlapping station walksheds.

The alignments offer ten-minute walk access to similar numbers of 2040 jobs (with a range of plus/minus 5%). The Central Artery Four-Track alignment walkshed yields the greatest number of jobs, which is unsurprising as its third station provides access to a greater area of Downtown Boston. Out of the alternatives with only two stations, the South/Congress walkshed encompasses a slightly higher number of jobs, likely because of its combination of good access from both the State-Haymarket location and the South Street entrance to South Station. The Central Artery Two-Track and Four-Track alternatives provide good access to the Seaport area (where employment is expected to grow significantly by 2040), but less access to other parts of the Financial District. Figures 56 through 60 show the walksheds from stations for each alignment, as well as the walkshed for the existing North and South Stations.

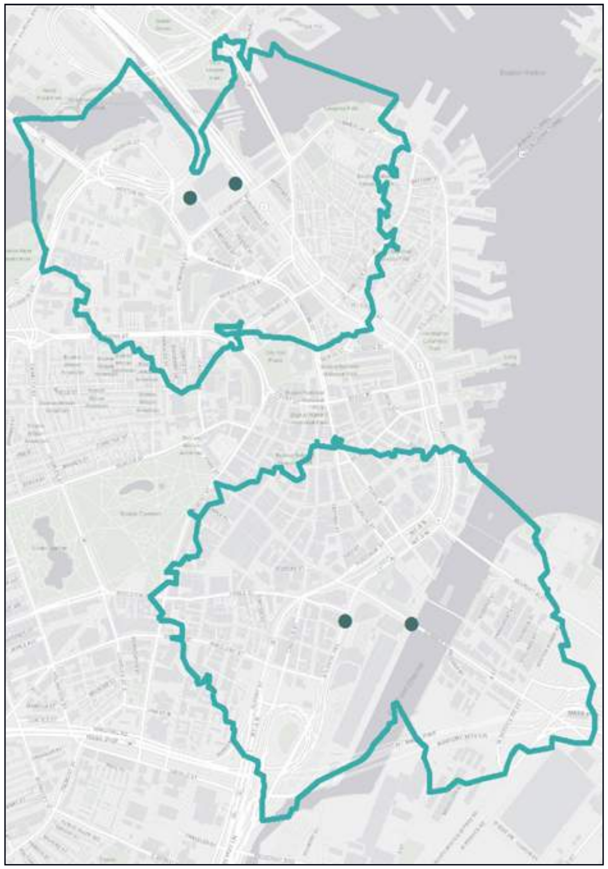

Figure 56: No Build and Surface (No NSRL) Walkshed (Existing Conditions)

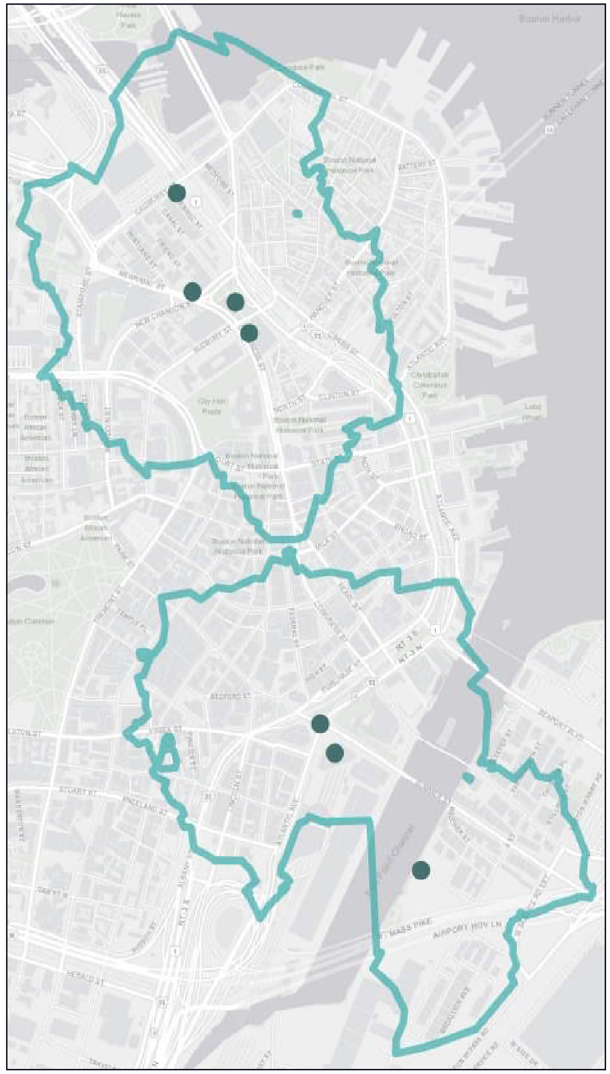

Figure 57: Central Artery Two-Track Walkshed

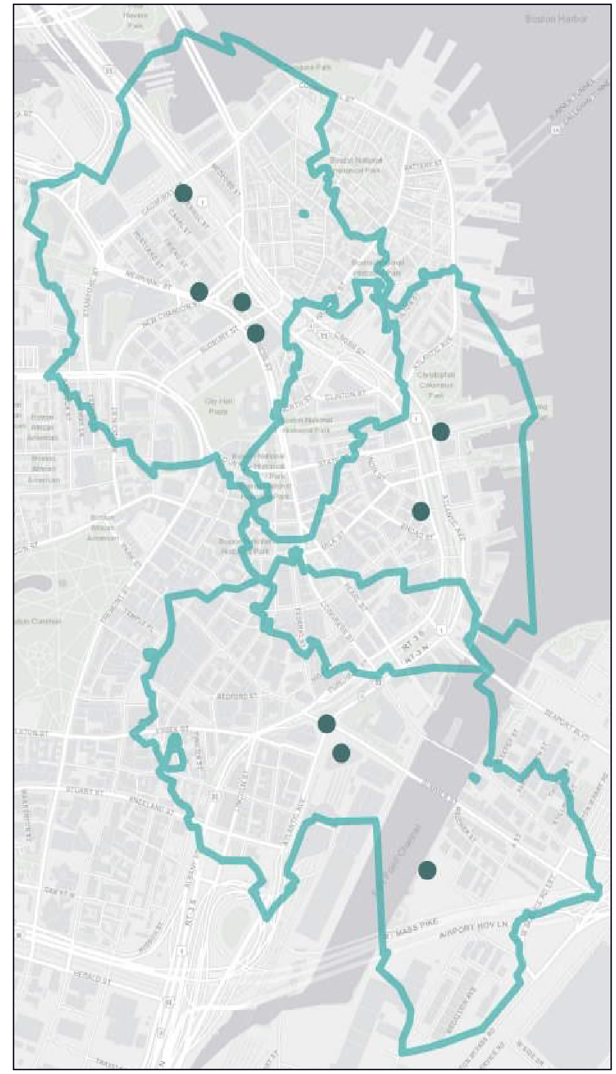

Figure 58: Central Artery Four-Track Walkshed

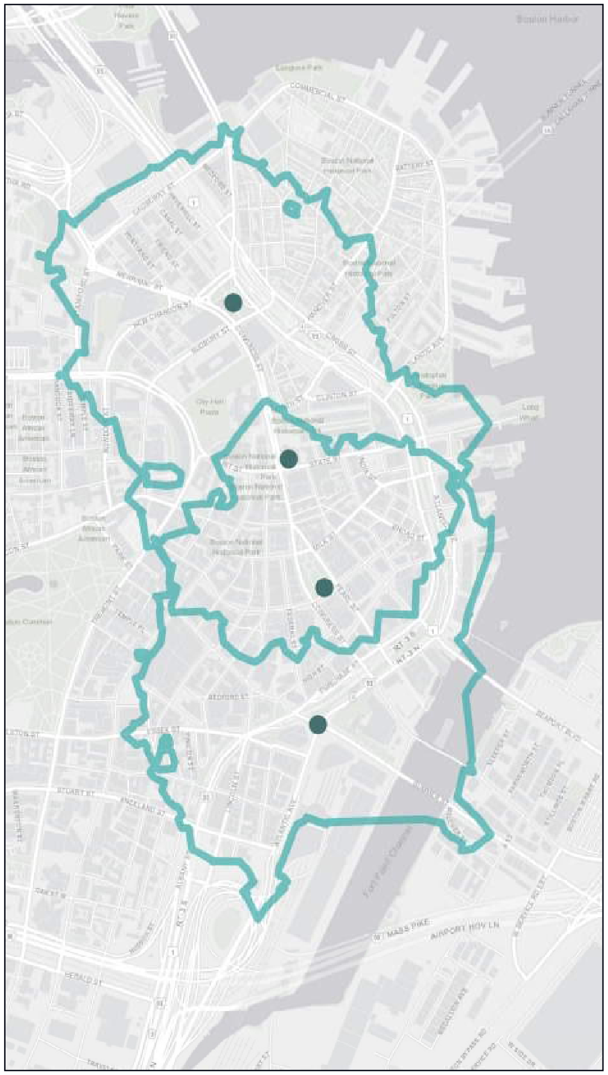

Figure 59: Pearl/Congress Walkshed

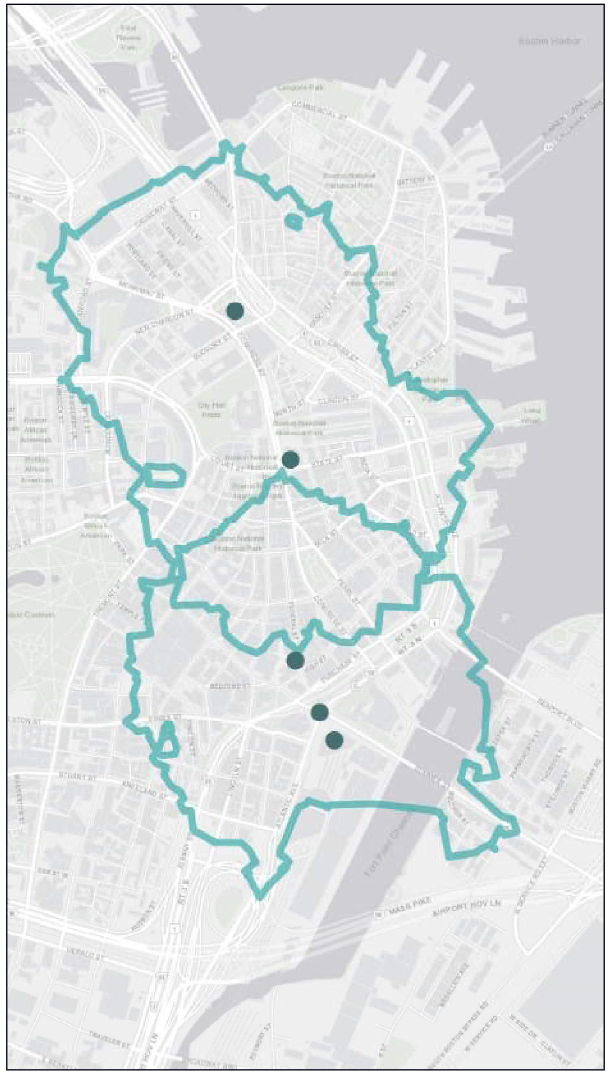

Figure 60: South/Congress Walkshed

MBTA Commuter Rail Travel Time Savings

MBTA Commuter Rail travel time savings come from two sources:

- **Existing users** who will benefit from service improvements
- **New users** who are anticipated to shift automobile to commuter rail because of a more convenient and faster rail service

Existing Rail Users

Benefits to existing MBTA Commuter Rail users arise primarily from an increase in the frequency of trains and connectivity. The CTPS travel demand model estimates that on average, existing riders save three minutes per trip in the South Station Expansion & All-Day Peak Service (No NSRL) alternative and 6.5 minutes per trip in the NSRL All-Day Peak Service (both Two-Track and Four-Track), compared to the No Build alternative. The travel time savings double in the Two-Track and Four-Track alternatives, due to the connectivity and walkability improvements of linking the north side and south side commuter rail systems. Though the savings may seem modest at the individual level, in the aggregate they represent millions of hours saved per year; and for certain trips, the individual time savings can be substantial (details are in Table 33). Savings total approximately two million hours for the South Station Expansion & All-Day Peak Service (No NSRL) alternative and more than four million hours for both the NSRL All-Day Peak Service (both

Two-Track and Four-Track) alternatives, as shown in Table 32.

The benefits from improved MBTA Commuter Rail service were estimated by using the No Build 2040 ridership numbers (150,000 daily riders) as a baseline and allocating the average travel time savings per trip from each build alternative. A factor of 271 (per CTPS guidance) was used to convert daily values into annual numbers.

Sample Trips

To better understand the more specific travel time impacts of the NSRL, a number of sample trips were identified. These sample trips were a mix between those that can be completed by MBTA Commuter Rail today, and those that currently require multiple transfers. As Table 33 shows, the trips that benefit the most from the NSRL tunnel being constructed see time savings ranging from 20-40%, (depending on the build alternative), while others of this same type see a more modest improvement in travel times (less than 10%).

	South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (both Two-Track and Four-Track)
Daily (min)/trip saved	3.0	6.5
Total daily hours saved	7,500	16,250
Total Annual hours (x 271)	2,032,500	4,403,750

Table 32: 2040 Existing Commuter Rail Users - Average Travel Time Savings per Alternative Compared to No Build

Source: Estimates based on CTPS data

From	To	Existing		No Build		NSRL All-Day Peak Service (Two-Track)		NSRL All-Day Peak Service (Four-Track)	
		Path/Routes	Min	Path/Routes	Min	Path/Routes	Min	Path/Routes	Min
Waltham Station	Back Bay Station	Fitchburg -> Red -> Orange	56	Fitchburg -> Red -> Orange	54	Fitchburg	40	Fitchburg	42
Lynn Station	Seaport (Seaport Blvd / Boston Wharf Rd)	Rockport/ Newburyport -> SL3 -> Walk from WTC	50	Rockport/ Newburyport -> SL3 -> Walk from WTC	50	Rockport/ Newburyport -> Walk	47	Rockport/ Newbury-port -> Walk	48
Lowell Station	Ruggles Station	Lowell -> Orange	75	Lowell -> Orange	74	Lowell/ Providence	66	Lowell/ Providence	66
W. Roxbury Station	Brandeis-Roberts Station	Needham -> Red -> Fitchburg	88	Needham -> Red -> Fitchburg	87	Fitchburg/ Needham	68		
Route 128 Station	Winchester Station	Providence -> Red -> Orange -> Lowell	88	Providence -> Red -> Orange -> Lowell	86	Providence/ Lowell	48	Providence/ Lowell	44

Table 33: Sample Trips on CR Network – Existing and No Build/Build Alternatives

Note: Travel time includes initial wait time, transit run time, transfer walk time, and transfer wait time

New Rail Users

The CTPS model estimates both the number of trips that would shift from automobile to MBTA Commuter Rail and the travel time savings for these new commuter rail users. Table 34 shows that the South Station Expansion & All-Day Peak Service (No NSRL) alternative is expected to save travelers who shifted from auto to commuter rail 45 daily hours compared to the No Build, and the NSRL All-Day Peak Service (both Two-Track and Four-Track) alternatives are expected to generate twice as much travel time savings than the South Station Expansion & All-Day Peak Service (No NSRL) alternative. On an annual basis, the South Station Expansion & All-Day Peak Service (No NSRL) alternative would save about 12,200 hours, the NSRL All-Day Peak Service (Two-Track) alternative 25,600 hours and NSRL All-Day Peak Service (Four-Track) alternative 28,500 hours.

		South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (Two-Track)	NSRL All-Day Peak Service (Four-Track)
A)	Daily Hours Saved	35	77	85
B)	Daily Hours Saved Adjusted for Vehicle Occupancy (A x 1.2)	45	95	105
C)	Total Annual Hours (B x 271)	12,200	25,600	28,500

Table 34. 2040 New Commuter Rail Users – Average Travel Time Savings per Alternative Compared to No Build

Source: Estimates based on CTPS data. Numbers were rounded.

Roadway Impacts

Roadway Benefits: Vehicle Hours Traveled

Roadway benefits are measured as travel time savings (quantified as vehicle hours traveled, or VHT). These benefits accrue to those travelers who continue to commute by automobile in 2040 for all build alternatives, as compared to the No Build. This is due to less congestion on the highway network as some auto travelers shift to commuter rail. Annual travel time savings for auto drivers could attain three million hours for the South Station Expansion &

		South Station Expansion & All-Day Peak Service (No NSRL))	NSRL All-Day Peak Service (Two-Track)	NSRL All-Day Peak Service (Four-Track)
A)	Potential Daily VHT Saved (adjusted for Vehicle Occupancy) in Hours	11,285	26,560	29,510
B)	Potential Annual VHT Saved, in Hours (A x 271)	3,055,000	7,197,490	7,997,210

Table 35. 2040 Auto Users – Potential Annual VHT Savings per Alternative Compared to No Build

Source: Estimates based on CTPS data. Numbers were rounded.

All-Day Peak Service (No NSRL) alternative, about seven million hours for the NSRL All-Day Peak Service (Two-Track) alternative and almost eight million hours for the NSRL All-Day Peak Service (Four-Track) alternative.

Roadway Benefits: Vehicle Miles Traveled

For those commuters who shifted from automobile to MBTA Commuter Rail, VMT declines for all project alternatives. This is attributed to the fact that these travelers are driving less and as a result will experience savings in their vehicle operating and maintenance costs.

Highway Capacity

There is substantial research indicating that, absent market pricing policies, increases in capacity do not result in less highway congestion. A study from the National Center for Sustainable Transportation at UC Davis notes that adding highway "capacity decreases travel time, in effect lowering the 'price' of driving; and when prices go down, the quantity of driving goes up. Induced travel counteracts the effectiveness of capacity expansion as a strategy for alleviating traffic congestion. It also offsets (in part or in whole) reductions in GHG emissions that would result from reduced congestion."[23] In the context of the NSRL project, the reductions in VMT may not occur, however an increase in regional transportation capacity is created.

		South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (Two-Track)	NSRL All-Day Peak Service (Four Track)
A)	Daily VMT Reduction vs No Build	203,000	394,800	438,700
B)	Annual VMT Reduction (A x 271)	55,000,000	106,990,800	119,000,000

Table 36. 2040 Auto Users - Annual VMT Savings per Alternative Compared to No Build

Source: Arup estimates based on CTPS data. Numbers were rounded.

Impacts to Rapid Transit

The CTPS model results suggest that in the build alternatives, as MBTA Commuter Rail service increases, MBTA rapid transit forecast ridership increases moderately. In the No Build alternative, the model forecasts that ridership on the Green, Red, Orange and Blue Lines will increase about 18% from today's ridership (to about 950,000 daily trips in 2040). For the South Station Expansion & All-Day Peak Service alternative, rapid transit ridership decreases by about 7,500 daily riders from the No Build alternative (less than 1% fewer passengers). For the NSRL All-Day Peak Service (Two-Track) alternative, rapid transit ridership decreases about 25,000 daily riders from the No Build (about 2.5% fewer passengers), and for the NSRL All-Day Peak Service (Four-Track) alternative, rapid transit ridership decreases by 32,000 daily riders (about 3.4% fewer passengers).

Compared to the No Build alternative, the CTPS model identifies a reduction in peak period rapid transit ridership as well – about 6,600 passengers, or about 4,000 passengers in the peak hour. The Orange Line is likely to experience the largest reduction, driven by the reduction in transfers from North Station to the southbound Orange Line in the mornings and northbound in the afternoons. The Orange Line has a policy capacity of about 850 passengers per train, and the reduction in demand could approach the equal of four full trains.

	No Build	South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (Two-Track)	NSRL All-Day Peak Service (Four-Track)
Daily Ridership	950,000	935,000	926,000	918,000
Difference from No Build (absolute)	-	-7,500	-24,000	-32,000
Difference from No Build (%)	-	-1.0%	-2.5%	-3.4%

Table 37. 2040 Rapid Transit Ridership per Alternative Compared to No Build

Source: Analysis based on CTPS data. Numbers were rounded.

Other cities have used or are using commuter rail systems to supplement crowded rapid transit lines, and the CTPS model indicates a similar potential for the MBTA with the NSRL project. More service on the MBTA Commuter Rail network, enhanced by the provision of tunnel service through Downtown Boston, could play a key role in alleviating rapid transit overcrowding in future years.

Quantification of benefits

The CTPS ridership forecasts provide the basis for further analysis of project benefits. Table 38 summarizes the mobility benefits by each build alternative.

The model also estimates the MBTA Commuter Rail emissions, which increase between alternatives because higher levels of service requires increased usage of diesel locomotives. The emissions results also consider that the Two-Track and Four-Track build alternatives have more electrified service than the No Build or South Station Expansion & All-Day Peak Service alternatives (impacting emissions). The results are shown in Table 39.

2040 Benefits	South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (Two-Track)	NSRL All-Day Peak Service (Four-Track)
Impacts on Commuter Rail Users			
Number of Riders (daily weekday)	195,000	225,000	250,000
Daily Travel Time Savings per Rider (mins.)	3	6.5	6.5
% Trips – Work Related	83%	83%	83%
% Trips – Non-work Related	17%	17%	17%
Number of Daily Vehicle Trips Shifted to Transit	20,100	47,215	52,500
Total Daily Travel Time Savings from New Commuter Rail Users Shifted from Auto (hrs)	34	77	85
Total Daily Travel Time Savings Adjusted for Occupancy (X 1.2) (hrs)	42	95	105
Roadway & Air Quality Impacts (daily)			
Total VHT Reduced Adjusted for Occupancy (hrs)	11,280	26,559	29,500
Total VMT Reduction	203,000	394,800	438,700
Total Vehicle CO2 Reduction (metric tons)	55	107	118
Other Assumptions			
Annualization Factor	271		
Vehicle Occupancy Rate (persons/vehicle) *	1.2		

Table 38: 2040 Benefits by Project Alternative, Compared to No Build

**From CTPS Model. Numbers have been rounded.*

7.3 Operational Efficiencies

Under the various service alternatives identified in Chapter 4, rail operations increase substantially, from about 16,400 weekday daily train revenue miles to about 51,500 miles for the NSRL All-Day Peak Service (Two-Track) alternative and 55,000 miles for the NSRL All-Day Peak Service (Four-Track) alternative.

With this substantial increase in service, the maintenance needs of the system both increase and maintenance availability decreases. The MBTA currently performs track maintenance during midday periods, and with all-day peak levels of service, these maintenance windows would need to shift to nighttime to accommodate required work. In addition, with more service, maintenance needs – including trackwork and equipment maintenance – will increase.

As a benefit, the need to shuttle trains to the Boston Engine Terminal (BET) on the north side of the rail system, usually via the existing Grand Junction branch, will be substantially reduced. Currently, about 14 trains a week are required to move between BET and the south side rail system.

MBTA shuttles about one train daily in each direction from BET to the south side rail system. Assuming 20 miles as an average length for this journey, the total annual cost for these moves is about $2.5 million.

2040 Commuter Rail Emissions (in metric tons)	No Build	South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (Two-Track)	NSRL All-Day Peak Service (Four-Track)
CO_2 Commuter Rail Emissions (daily)	125	325	290	335
% Diesel Locomotives in Fleet	100%	95%	68%	73%

Table 39. CO_2 Commuter Rail Emissions by Project Alternative

Source: CTPS Travel Demand Model, rounded numbers

Weekly Trains	Number of Cars	Miles	Car Miles weekly	Car Miles Annually	Cost per Car Mile	Annual Cost
14	10	20	2,800	140,000	$17	$2.5 mil

Table 40: 2018 Weekly MBTA Commuter Rail Non-Revenue Miles

7.4 Economic Impacts

Land Redevelopment

Just as the NSRL project has the potential to change travel patterns, it also can have an impact on existing and potential land uses, creating opportunities for the development of new housing units and changes in the location and number of jobs in the Greater Boston area. Three parcels, totaling about 50 acres of land, could be redeveloped, as shown in Table 41.

The development potential is a function of the Project Alternative as described below:

- In the **South Station Expansion & All-Day Peak Service (No NSRL)** alternative there is limited opportunity for redevelopment. Neither North Station nor Widett Circle can be freed up for real estate development because these parcels would be needed to operate the system. In the case of the Fort Point US Post Office parcel, the SSX TREDIS® Methodology study performed in 2014 suggests that about 280 households and about 1,300 employees could be located on the site, which is shared with the South Station Expansion project proposals.
- In the **NSRL All-Day Peak Service (both Two-Track and Four-Track) alternatives** the real estate development potential is maximized, since all three parcels discussed above could be fully redeveloped. The total area for redevelopment is estimated at 48.8 acres.

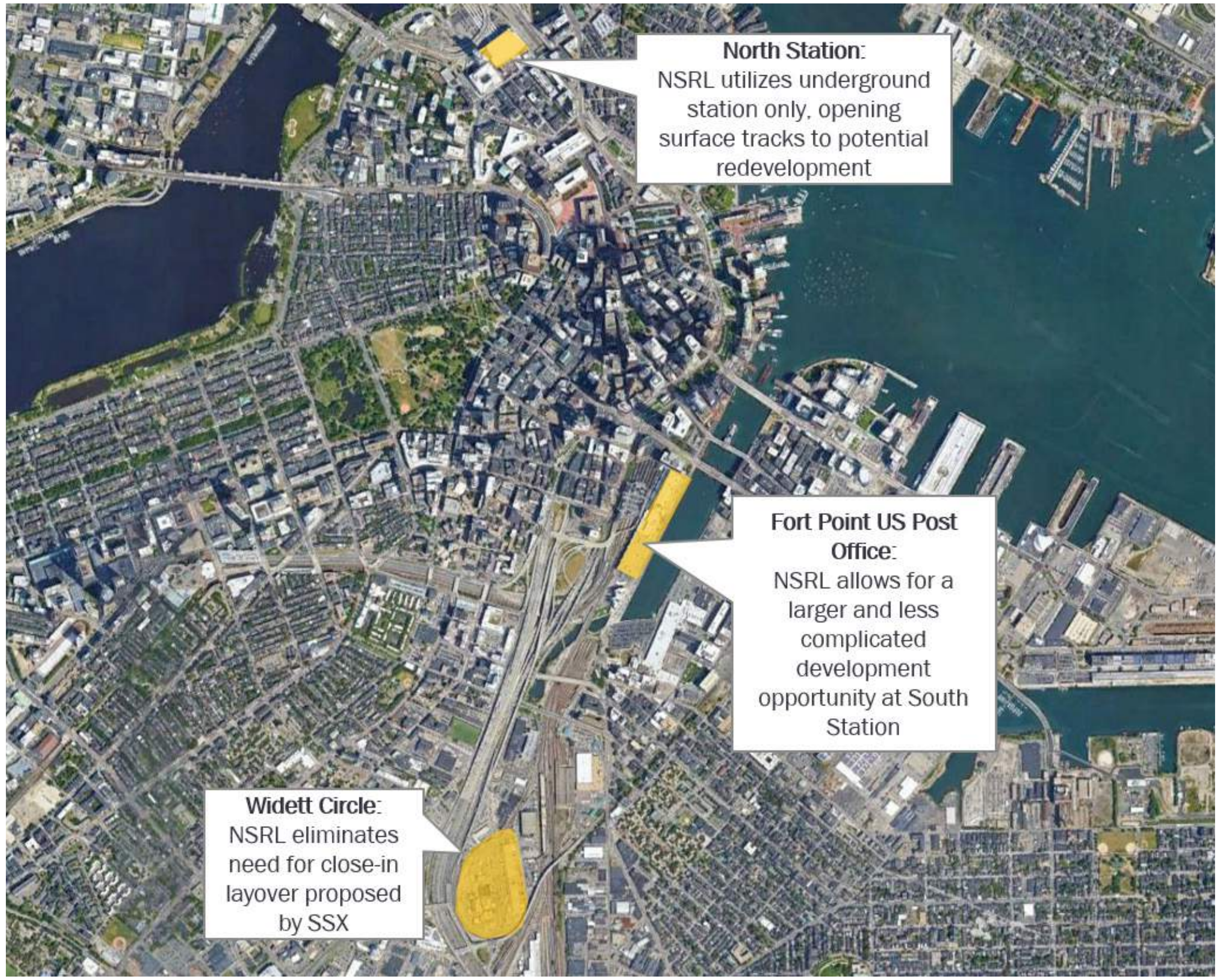

Figure 61: Map of Parcel Locations

Estimations for the size of potential redevelopment relied on data from parcels that were recently developed and located in proximity to the parcels under analysis. The Hines Tower was used as a reference for the Fort Point US Post Office parcel, the Hub on Causeway development was used as a reference for North Station, and South Bay Town Center was used as a reference for Widett Circle.

In the case of the Fort Point US Post Office parcel, a maximum Floor Area Ration (FAR) of 10 was used, based on the Planned Development Area for the South Station Air Rights Development Sub-Area. The proposed Hines Tower development footprint includes non-developable areas, which limits the maximum effective FAR.

Based on the FAR from the reference projects, the three parcels have a redevelopment potential of up to 15 million gross square feet (GSF). The number of jobs that could be accommodated per type of land use was based on data developed by the U.S. Green Building on building occupancies per building activity (sq.ft. per employee). The data suggest a median of 250 sq.ft. per employee for office uses and 550 sq.ft. per employee for commercial/retail. The results are shown in Table 43.

Parcel	Parcel Size	South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (both Two-Track and Four-Track)
Fort Point US Post Office	12 acres	~10%* of site	Developable
North Station	5.5 acres	Non-Developable	Developable
Widett Circle	31.3 acres	Non-Developable	Developable
Total	**48.8 acres**	**1.2 acres**	**48.8 acres**

Table 41: Development Potential per Alternative

*Source: Project estimates. Note: *Based on information from South Station Expansion Project: TREDIS Methodology, September 3, 2014.*

Parcel	Hines Tower* Area	Hub on Causeway	South Bay Town Center
Parcel Size (sq.ft.)	-	121,000	442,000
Development (sq.ft.)	-	1.9m	1.1m
Floor-Area Ratio (FAR)	10	15.6	2.5
Uses			
Residential	10%	29%	40% (475 units)
Office	78%	43%	0%
Commercial/Retail	12%	22%	26%
Other (Green Space/ Circulation/ Parking)	0%	6%	34%

Table 42. References for Land Redevelopment Estimates

Source: Based on publicly available information

As Table 44 shows, depending on the alternative, the potential for redevelopment ranges from about 1,300 job locations in the South Station Expansion & All-Day Peak Service (No NSRL) alternative, to about 15m of potential developable GSF under the NSRL All-Day Peak Service (both Two-Track and Four-Track) alternatives, accommodating about 28,000 jobs and almost 4,000 residential units.

Economic Impact of Construction and Operation Expenditures

The economic impacts of both the construction and operation expenditures of the NSRL project were estimated based on the input-output model (RIMS II) developed by the Bureau of Economic Analysis.

RIMS II is a regional economic model used to assess the potential economic impacts of various projects. The model produces multipliers that estimate the total impact of a project (new construction, tourism, etc.) on a region. It assumes that an initial change in economic activity results in a cascade of effects that stimulate other sectors in the economy. For example, building the NSRL project would lead to increased production of concrete. The increased production of concrete would lead to more mining and the workers hired due to the increase in economic activity would spend more in the region.

The Boston-Cambridge-Newton and MA-NH Metropolitan Statistical Area are considered the geographic coverage areas for this analysis. Type II

Parcel	Fort Point US Post Office *	North Station	Widett	Total
Total Potential Developable GSF	5.2 m	3.7m	5.6m	15m
Residential Units	520	1,050	2,380	3,950
Office Sq.ft.	4.0 m	1.6 m	0.0 m	5.6m
Retail/Commercial Sq.ft.	0.6 m	0.8 m	0.4m	2.9m
Number of Office Jobs	16,300	6,400	0	22,700
Number of Commercial/Retail Jobs	1,100	1,500	2,650	5,250
Total Jobs	17,400	7,900	2,650	27,950

Table 43: Development Potential per Parcel

Source: Estimates based on 2016 LEED Reference for Building Design and Construction, U.S. Green Building

*Note: *Uses FAR of 10, the maximum currently permissible in the area. Rounded numbers.*

Parcel	South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (both Two-Track and Four-Track)
Total Potential Developable GSF	N/A	15m
Number of Jobs	1,300*	27,950
Housing units	280*	3,950

Table 44: Development Potential per Alternative

Source: Estimates based on 2016 LEED Reference for Building Design and Construction, U.S. Green Building

**Based on information from South Station Expansion Project: TREDIS Methodology, September 3, 2014.*

multipliers were used to quantify the direct, indirect and induced economic impacts of the construction and operating phases of the project, as shown in Table 45. Multipliers from the construction industry for the construction phase and from the rail industry for the operating phase were also used.

The metrics generated by RIMS include:

- The model output corresponds to total sales, the aggregation of all impacts on the economy (direct, indirect, and induced)
- The earnings multipliers measure the total change in local household earnings per dollar of final-demand change, in this case the construction and operating expenditure of each project alternative. Earnings consist of wages and proprietors' income, and the net earnings of sole-proprietors and partnerships.
- The employment multipliers measure the total change in the number of local jobs per dollar of final-demand change (construction and operating expenditure). Employment is measured in both full- and part-time jobs.
- The value-added multipliers measure the total change in local value added per dollar of impact/ final demand change construction and operating expenditure). The value added is comparable to regional measures of the gross domestic product.

As the RIMS II multipliers show, the construction industry has higher multipliers than the rail transportation industry. For each dollar spent on a construction project, $1.72 is generated, whereas

Industry	Output (per USD)	Earnings (per USD)	Number of Jobs (per million USD)	Value Added (per USD)
Construction	1.72	0.50	9.25	0.95
Rail Transportation	1.59	0.36	5.60	0.87

Table 45: RIMS Type II Economic Multipliers

Source: RIMS II multipliers

for each dollar spent in the rail industry, $1.59 is generated. This is not surprising as the construction industry is a sector with one of the highest cascade effects on the economy.

The resulting impacts for the construction and operating phases of the various NSRL project alternatives are shown in Tables 46 and 47. The economic impacts correspond to the capital expenditures during the construction phase and to the operating expenditures during the operating phase. The higher the expenditure on either the construction or the operating phases, the higher the economic impact. The NSRL All-Day Peak Service (Four-Track) alternative, with a construction cost of more than $15bn, would generate an increase in the regional GDP of a similar size ($14bn) and would create around 140,000 jobs within a seven-year period. In comparison, the South Station Expansion & All-Day Peak Service (No NSRL) alternative, with a construction cost of near $3.7bn, would generate an increase in the regional GDP of $3.5bn and would create around 34,000 jobs within a six-year period. The results of Table 46 have been obtained by multiplying the capital expenditure of each project alternative by the relevant multipliers.

The economic impact from operating expenditures suggest that the NSRL All-Day Peak Service (Four-Track) alternative would generate the highest impact, followed by the NSRL All-Day Peak Service (Two-Track) and the South Station Expansion & All-Day Peak Service (No NSRL) alternatives, given the respective sizes of their operating budgets.

	2018 USD (in millions)				
Project Alternatives	Capital Expenditure	Output	Earnings	Number of Jobs	Value Added
South Station Expansion & All-Day Peak Service (No NSRL)	3,700 (six-year construction phase)	6,350	1,860	34,240	3,500
NSRL All-Day Peak Service (Two-Track)	9,500 (seven-year construction phase)	16,300	4,770	87,900	9,000
NSRL All-Day Peak Service (Four-Track)	15,200 (seven-year construction phase)	26,086	7,629	140,655	14,400

Table 46: Total Economic Impact on Greater Boston - Construction Phase

Source: Estimates based on RIMS II

	2018 USD (in millions)				
Project Alternatives	Operating Expenditure	Output	Earnings	Number of Jobs	Value Added
South Station Expansion & All-Day Peak Service (No NSRL)	360	573	130	2,014	310
NSRL All-Day Peak Service (Two-Track)	503	801	181	2,815	440
NSRL All-Day Peak Service (Four-Track)	557	887	201	3,117	485

Table 47: Total Economic Impact on Greater Boston – Operations Phase

Source: Estimates based on RIMS II

7.5 Environmental Justice Analysis

Environmental justice (EJ) principles seek to "avoid, minimize or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects on minority populations and low-income populations" and to "prevent the denial or, reduction in, or significant delay in the receipt of benefits by minority and low-income populations." Community participation is also a key principle.[24] Fair treatment of all people is considered paramount.

The NSRL project has the ability to either improve the quality of life and the economic status of minority and low-income communities, or to make it worse. Better transportation can enhance access to employment opportunities benefiting everyone, but more diesel trains adjacent to neighborhoods could make air quality in these areas worse.

To access the distribution of EJ-related economic benefits of the NSRL project, employment accessibility for three types of jobs – basic, retail and service (see descriptions below), is examined for EJ communities and compared against non-EJ communities. The purpose of the analysis is to determine if benefits are reasonably distributed among EJ and non EJ communities.

Based on an analysis with data developed in the CTPS modeling process, NSRL has the following economic impacts:

- Accessibility: The results suggest that in general, minority EJ and non-EJ communities improve their accessibility to jobs in all build alternatives when compared against the No Build.
- Distribution of benefits: The results from the statistical test suggest that both minority EJ and non-EJ communities benefit from the project under the South Station Expansion & All-Day Peak Service (No NSRL) and NSRL All-Day Peak Service (Four-Track) alternatives, and neither is benefiting more than the other.
- Under the NSRL All-Day Peak Service (Two-Track) alternative, improvements in job accessibility tend to benefit more one group over the other. Accessibility improvements to retail and service jobs are benefiting slightly more minority EJ communities than non-EJ communities, whereas accessibility to basic jobs seems to improve slightly more for non-EJ communities

Definitions and Thresholds

Basic employment includes jobs that are typified as "blue collar", which include but are not limited to jobs in manufacturing, laboratories, warehousing and transportation. Service employment includes jobs that are typified as "white collar", which can include government, finance, insurance, and service jobs (excluding jobs in education). Retail employment refers to the jobs supporting the retail trade. The year 2040 employment projection has been adopted by the Boston Region MPO and used in its LRTP.

The study area for the EJ analysis uses the MBTA service area, defined earlier in this report and used in the MBTA's 2017 Title VI report.[25]

Two thresholds (race and ethnicity) were used to designate a TAZ an EJ community:

1. Minority EJ communities have minorities making up more than 28.19% of the population for that TAZ.
2. Low-Income EJ communities are where the median income is less than $45,253 (60% of the MPO median income).

To estimate the impact all alternatives could have on employment accessibility by market segment (income and ethnicity), the analysis compared the change in number of jobs that could be reached by these market segments in all alternatives (build and No Build), using a fixed travel time of 40 minutes. Each alternative implemented some of the following changes to the commuter rail system that in turn changed the number of jobs that were accessible.

- In-vehicle travel time on the commuter rail lines
- Frequency
- Fares
- New Downtown Boston station location
- Connectivity of the north side to the south side of the rail network

A T test[26] determines whether the differences between EJ and non-EJ communities are statistically significant. The hypothesis of the test is that there is no difference between EJ and non-EJ communities in terms of the changes in accessibility generated by the NSRL project (in other words, the benefits are equally distributed).

	Basic Jobs		Retail Jobs		Service Jobs	
	EJ	Non-EJ	EJ	Non-EJ	EJ	Non-EJ
No Build	25,466	28,794	35,553	39,553	258,917	278,212
South Station Expansion & All-Day Peak Service (No NSRL)	25,597	28,876	35,675	39,502	260,387	278,246
Comparison of No Build vs. No NSRL	0.51%	0.28%	0.34%	-0.13%	0.57%	0.01%
t- test	0.8895		0.2730		0.9007	
(EJ vs non-EJ)	(statistically insignificant)		(statistically insignificant)		(statistically insignificant)	
	Basic Jobs		Retail Jobs		Service Jobs	
	EJ	Non-EJ	EJ	Non-EJ	EJ	Non-EJ
No Build	25,466	28,794	35,553	39,553	258,917	278,212
NSRL All-Day Peak Service (Two-Track)	25,720	29,127	36,089	39,968	262,766	280,301
Comparison of No Build vs. Two-Track	1.00%	1.16%	1.51%	1.05%	1.49%	0.75%
t- test	0.0003		0.0004		0.0022	
(EJ vs non-EJ)	(statistically significant)		(statistically significant)		(statistically significant)	
	Basic Jobs		Retail Jobs		Service Jobs	
	EJ	Non-EJ	EJ	Non-EJ	EJ	Non-EJ
No Build	25,466	28,794	35,553	39,553	258,917	278,212
NSRL All-Day Peak Service (Four-Track)	32,996	35,132	45,527	47,935	322,477	326,951
Comparison of No Build vs. Four-Track	.57%	22.01%	28.05%	21.19%	24.55%	17.52%
t- test (p value)	0.1855		0.2239		0.3901	
(EJ vs non-EJ)	(statistically insignificant)		(statistically insignificant)		(statistically insignificant)	

Table 48. Job Access for Minority EJ and Non-EJ Communities

Source: CTPS

	Basic Jobs		Retail Jobs		Service Jobs	
	EJ	Non-EJ	EJ	Non-EJ	EJ	Non-EJ
No Build	23,588	28,019	34,361	38,326	258,034	270,949
South Station Expansion & All-Day Peak Service (No NSRL)	23,857	28,082	34,707	38,281	261,079	271,106
Comparison of No Build vs. No NSRL	1.14%	0.22%	1.01%	-0.12%	1.18%	0.06%
T- test	0.2931		0.3473		0.7041	
(EJ vs non-EJ)	(statistically insignificant)		(statistically insignificant)		(statistically insignificant)	

	Basic Jobs		Retail Jobs		Service Jobs	
	EJ	Non-EJ	EJ	Non-EJ	EJ	Non-EJ
No Build	23,588	28,019	34,361	38,326	258,034	270,949
NSRL All-Day Peak Service (Two-Track)	23,750	28,347	34,742	38,832	261,644	273,789
Comparison of No Build vs. Two-Track	0.68%	1.17%	1.11%	1.32%	1.40%	1.05%
T- test	0.0023		0.0052		0.0067	
(EJ vs non-EJ)	(statistically significant)		(statistically significant)		(statistically significant)	

	Basic Jobs		Retail Jobs		Service Jobs	
	EJ	Non-EJ	EJ	Non-EJ	EJ	Non-EJ
No Build	23,588	28,019	34,361	38,326	258,034	270,949
NSRL All-Day Peak Service (Four-Track)	31,872	34,612	45,295	47,063	329,827	323,176
Comparison of No Build vs. Four-Track	35.12%	23.53%	31.82%	22.79%	27.82%	19.28%
T- test	0.8338		0.6399		0.5134	
(EJ vs non-EJ)	(statistically insignificant)		(statistically insignificant)		(statistically insignificant)	

Table 49. Job Access for Low-Income EJ and Non-EJ Communities

Source: CTPS

7.6 Air Quality Benefits

Air Quality Benefits: CO2 Emissions Reduction

Air quality benefits, measured as reductions in CO2 emissions, occur when there is a decrease in vehicle miles traveled. However, the increase in MBTA Commuter Rail service, assumed to be relying mainly on diesel locomotives, offsets reductions in CO2 emissions from driving, and thus air quality benefits are eliminated, as displayed in Table 50. If the NSRL project had included systemwide electrification, the emissions from diesel locomotives would be eliminated, but at a significant increase in capital costs for the project. Should the NSRL advance in a future in which the MBTA has already electrified the commuter rail network, the increased service levels would not increase emissions (as they do in this Feasibility Reassessment).

The Global Warming Solution Act sets statewide greenhouse gas (GHG) emission reduction goals of 10-25% below statewide 1990 GHG emission levels by 2020 and 80% below statewide 1990 GHG emission levels by 2050.[27] The Massachusetts Department of Environmental Protection (MassDEP) reports that, based on recently available data, 2014 GHG emissions in the state were 21% below the 1990 baseline level. In the transportation sector, statewide VMT has remained steady, despite a modest increase in population.[28]

However, the continued use of diesel locomotives on the MBTA Commuter Rail impacts MassDOT compliance with the desired GHG reductions, as discussed above. Potential mitigations are the introduction of alternative fuel sources, including potential battery-electric traction, as discussed in Chapter 3.

Source of Emissions	No Build	South Station Expansion & All-Day Peak Service (No NSRL)	NSRL All-Day Peak Service (Two-Track)	NSRL All-Day Peak Service (Four-Track)
Commuter Rail	125	323	292	336
Automobile	36,733	36,679	36,668	36,615
Total	**36,858**	**37,002**	**36,960**	**36,951**
Difference from No Build*	-	(144)	(102)	(93)

Table 50. 2040 Rail and Auto CO2 Emissions for Project Alternatives

*Source: Based on CTPS travel demand model. *A positive number indicates net positive reductions in CO2 emissions*